

LONG-TERM TEMPERATURE MONITORING OF VOLCANIC AREAS BY DISTRIBUTED OPTICAL FIBER SENSORS

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Summary

We present the first results of long- term monitoring of temperature profiles at the Campi Flegrei caldera. The measurements were carried out along a 76 meters-deep borehole already equipped with a borehole strain-meter. We installed a cable containing a loop of optical fiber in order to use a fiber-optics distributed sensor based on stimulated Brillouin scattering. The obtained data are consistent with results of both deep and surface geothermal explorations and indicate that geothermal gradient can be efficiently measured and monitored by the proposed technique.

1. .Introduction

The measurements of the three-dimensional distribution of temperature represents an important objective of scientific studies, allowing to identify heat source(s), to determine thermal conductivity and the flow versus advective heat transport, to quantitatively model the thermal state, to interpret data from seismic, aeromagnetic and geochemical surveys [1]. Furthermore, temperature is one of the physical parameters of a volcano registering a characteristic increase

during reactivation periods. Hence, thermal monitoring is so one of the most important elements of an integral monitoring system.

The geothermal gradient measurements also allow a more realistic interpretation of data from seismic, geodetic gravimetric, magnetic and geochemical monitoring networks by the knowledge of temperatures at depth.

For this purpose, a temperature sensing system is needed, with by which temperature measurements can be performed simultaneously over long distances with a high spatial and temperature resolution. On the other hand, it must be ensured that the sensing technique (sensor and supply lines) itself is not a risk parameter (e.g. by short currents). The distributed fiber optical temperature sensing techniques offers these possibilities, especially for harsh environments.

Thermal gradient can easily and rapidly measured taking advantage of Brillouin fiber-optics distributed sensors [2, 3]. These sensors allow the measurement of temperature and/or strain profiles over distances up to a few kilometers by simply deploying a low-cost single-mode optical fiber in the area of interest.

We present the first results of long-term monitoring of temperature profile measurements at the Campi Flegrei caldera (see Fig. 1 for a Digital Terrain Modelling (DTM) map of the area of interest, for courtesy of the Lab Geomatica e Cartografia – INGV, Napoli, Giuseppe Vilardo). The Campi Flegrei caldera is considered among the highest risk volcanic areas in the world. The caldera in which now the western town of Napoli develops and 1 million people lives, hosted more than 60 explosive eruptions in the past 15 ky and at the present is the a site of intense hydrothermal, fumarolic and bradyseismic phenomena, that also preceded and accompanied the last magmatic unrest in AD 1538 [1]. Therefore, research and monitoring activities are continuously promoted and conducted both at national and international levels in order to understand the working of the volcano, to determine its present structure, to forecast its future evolution and to mitigate the volcanic hazard.

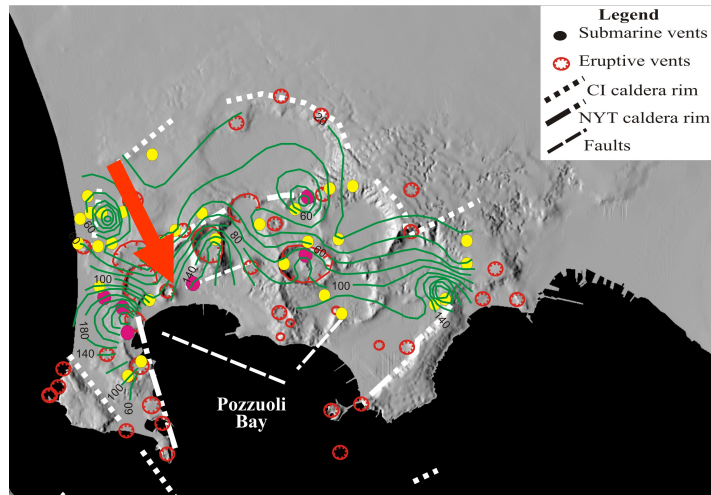


Figure 1. Digital Terrain Modelling (DTM) map of the Campi Flegrei caldera.

2. Experimental results

Temperature measurements were carried out along a 76 meters-deep borehole already equipped with a borehole strain-meter (the borehole location is indicated by the red arrow in the DTM map of Fig. 1). We installed a cable containing a loop of single-mode optical fiber in order to use a fiber-optics distributed sensor based on stimulated Brillouin scattering (SBS).

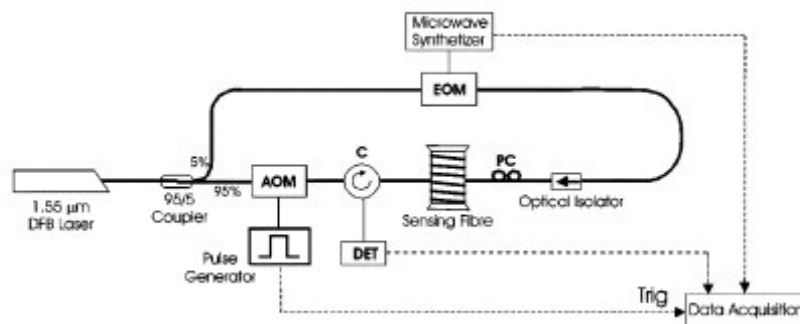


Figure 2. Experimental set-up for distribute temperature sensing. C = optical circulator. PC = polarization controller.

The two ends of the fiber loop were connected to a prototype for distributed temperature measurements. A sketch of the instrument employed for data acquisition is shown in Fig. 2. An acousto-optic modulator (AOM) was used to provide pulses with widths down to 20 ns, whereas the CW probe signal is generated by the electro-optic modulator using the sideband technique [4]. The detector consisted of an InGaAs photodetector and a preamplifier with a sensitivity of 4 mV/ μ A and an electrical bandwidth of 125 MHz, whereas the data acquisition rate was 625 MS/s. A frequency shift of 300 MHz is induced by the AOM on the pump optical frequency due to acousto-optic effect, so that only one of the two sidebands can effectively interact with the pump wave for Brillouin scattering generation. This occurrence eliminates the need for an optical bandpass filter in front of the detector, differently from the configurations usually proposed in the literature [4], providing an inherent stability to the system, the latter being totally immune to any drift on the source wavelength. Probe amplification was measured for a range of pump-probe frequency shifts, in order to extract the Brillouin gain spectrum at each sensing fiber location. Finally, each acquired Brillouin gain spectrum was fitted to a Lorentzian function, in order to retrieve the Brillouin frequency shift (which is proportional to the local temperature) at the corresponding fiber position.

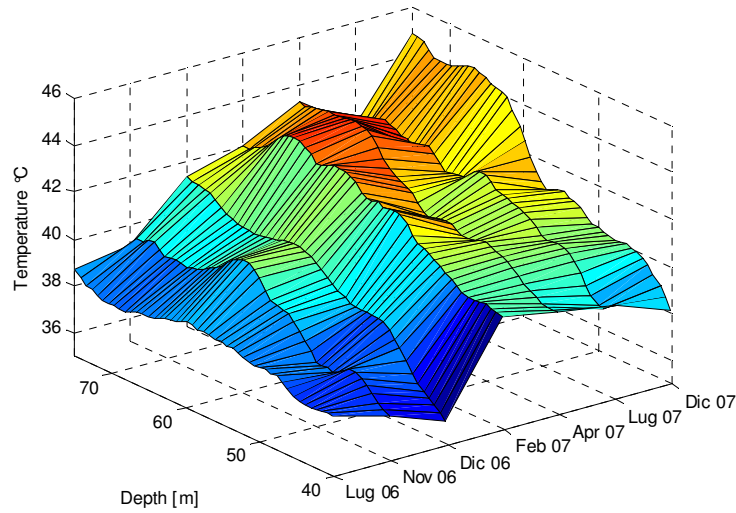


Figure 3. Temperature profile measurements along a borehole in Campi Flegrei caldera. Measurements were taken along a temporal span of about 1.5 years.

Temperature measurements were carried out with an accuracy of 2 °C and a spatial resolution of 2 meters. Observations were done in temporal span of about 1.5 years.

The results of the measurement campaign are shown in Fig. 3, showing the temperatures acquired along the deepest 30 meters of the borehole. The measurements show a progressive temperature increase with the depth. The obtained data are consistent with results of geothermal exploration [5] and indicate that geothermal gradient can be efficiently measured and monitored by the proposed technique.

References

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